

IN THE ABSTRACT:

Please add an Abstract of the Disclosure submitted herewith on a separate page.

REMARKS

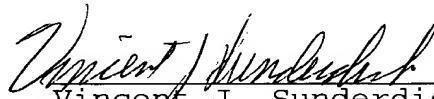
Entry of the amendments to the specification, claims and abstract before examination of the application is respectfully requested.

If there are any questions regarding this Preliminary Amendment or this application in general, a telephone call to the undersigned would be appreciated since this should expedite the prosecution of the application for all concerned.

It is respectfully requested that, if necessary to effect a timely response, this paper be considered as a Petition for an Extension of Time sufficient to effect a timely response and shortages in other fees, be charged, or any overpayment in fees be credited, to the Account of Evenson, McKeown, Edwards & Lenahan, P.L.L.C., Deposit Account No. 05-1323 (Docket #951/49160).

Respectfully submitted,

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1

TITLE OF THE INVENTION

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OPERATING METHOD FOR A DATA BUS WITH A PLURALITY OF NODES

This application claims the priority of German Patent Document 198 10 293.3 filed March 10, 1998 and PCT/EP99/01163 filed February 23, 1999, the disclosures of which are expressly incorporated by reference herein.

BACKGROUND AND SUMMARY OF INVENTION

The invention relates to an operational process for a data bus for a plurality of nodes as follows from the German Patent Application 19720401.5 not previously published. Each [telegram] message possesses an unambiguous identifier which determines the urgency of the [telegram] message.

The data bus [possess] includes, for at least [one part] some of the nodes, optical transmission segments [up to the star coupler]. [If it is an electric star coupler these] The [telegrams] messages are converted into [an] electric [signal telegram] signals and converted via a receiver/transmitter unit once again into a preferably optical signal telegram which is thus transmitted to all the remaining nodes. A data bus of this type with at least one partially optical transmission segment [possesses to that extent] include a particular characteristic [as] the signal transit time, that is, the time for the transmission of a signal [(telegram)] from one node to another is significantly greater than the bit time. In contradistinction thereto the signal transit time in

the case of a purely electrical data bus, as, for example, is frequently used in vehicles under the designation CAN, is significantly smaller than the bit time. An additional difficulty due to the sharply differing [of the] signal transit times arises when additional nodes are connected to the data bus which themselves output (only) electrical [signal telegrams] signals.

An example [may illustrate this. Let us assume], [as] is represented in Figure 1, which has a star-shaped bus system with [altogether] four nodes T1 to T4 in which nodes T1, T2, and T3 are connected via an optical transmission segment L1, L2, and L3 to an active electric star coupler K. Between each of the nodes T1 and T3 and the star coupler K two SE (transmitter/receiver) units SE_{11} , SE_{12} , SE_{21} , SE_{22} , SE_{31} , and SE_{32} are disposed in which the electrical [telegram] signal present originally at the nodes is converted into an optical signal and is reconverted into an electrical signal [telegram] which then is given to the star coupler K. In reverse, the optical telegrams intended for the nodes starting originally from the star coupler are converted into optical telegrams and then, in turn, into electrical receiver signals.

Furthermore, an additional node T4 is disposed which is [a node which is] connected via an electrical transmission segment directly to the star coupler K.

Depending on the conversion time [for] from the electrical into optical signals and vice versa (about on the order of magnitude of 60 - 100 ns each) and the transit time in the optical transmission segments (ca. 5 ns/m), transit times for [telegrams of] information from each of the nodes T1 to T3 to and from the star coupler K [follow which are specified] for example, in the exemplary embodiment [by way of example as] 180, 240, and 200 ns. The transit time of the signals from node T4 to the star coupler K is ideally equal to 0 ns.

If one assumes, for example, [a telegram which is supposed to go] information signals which are from node T1 to node T2 via the star coupler K, then a transit time of at least 420 ns results, for [a telegram] information signals from node T3 to T2 of [even] 440 ns. The minimal signal transit time for [telegrams here] signals between the nodes T1 and T4 is 180 ns.

It can be seen without further effort that the transit time in the system depends strongly on the respective individual delay times in the transmission segments of the individual nodes to the active star coupler and moreover is significantly greater than the bit time, here, for example, assumed equal to 100 ns.

Let us now assume signal traffic on the data bus as follows from Figure 2. [and the older patent application mentioned earlier.] Between two synchronization pulses which are output by a bus master, a data transaction takes place on the data

bus. In each of the cycles designated as cycle 1, cycle 2, and cycle 3 at most three [telegrams] signals are output which are the [telegrams] signals t₁, t₂, and t₃ or t₁, t₄ and t₅ or the [telegram] signal t₃ alone. Between each of the [telegrams] actually transmitted signals, there is at least one [wait] delay time [must be adhered] which follows from the following equation.

Wait time: $t_{wx} = t_{wx0} + t_{wx\Delta} \Delta * (ID - ID_{x-1})$

Therein t_{wx0} means a fixed percentage which serves to unambiguously distinguish [telegram] signal and wait time, $t_{wx\Delta}$ a fixed multiplication percentage which depends on the maximal signal transit time in the bus system, and $ID - ID_{x-1}$ the difference of the [telegram] signal identifier.

Therein ID stands for the identifier of the [telegram] signal to be actually [to be] sent by the node and ID_{x-1} for the identifier of the last [telegram] signal actually transmitted.

As can be easily seen, [without further effort] the distance is minimal between two transmitted signals, and with regard to their identifier, sequential [telegrams] signals, [therefore] (e.g., between the [telegrams] signals t₁ and t₂ or t₂ and t₃ as well as between t₄ and t₅). However, for [telegrams] signals not directly sequential with regard to their identifier, such as t₄ after t₁ in cycle 2, [it] the distance is greater.

[With the aid of Figure 3 the] The calculation of the multiplication percentage t_wx_delta following from the transit times [is to] can be explained with the aid of Figure 3.

[Let] If two nodes [be] are assumed, designated [here] as A and B, [.] then Node B transmits a [telegram] signal with ID = 1 and node A a [telegram] signal with ID = 2. Furthermore, [let] if node A be is assumed as bus master then Node A. [It] transmits the synchronization pulse and starts, after the end of the synchronization pulse, the wait time t_wx. [The node] Node B sees the end of the synchronization pulse but delayed by t_max and thus starts its wait time t_wx t_max later. Node B begins after the expiration of the wait time

$$t_{wx} = t_{wx0} = t_{wx_delta} * 1$$

with the transmission of the [telegram] signal ID = 1. This [telegram] signal in turn needs t_max in order to arrive at node A. Node A must still be able to receive this [telegram] signal before it, [for its part,] begins with the transmission of the [telegram] signal ID = 2. The following equations must therefore be satisfied from the standpoint of node A in order to avoid a collision.

Start time telegram ID = 2 > Receiving time telegram ID = 1

$$t_{wx0} + 2*t_{wx_delta} > t_{max} + t_{wx_delta} + t_{max}$$

[For] From this it follows:

$$t_{wx_delta} > 2*t_{max}$$

In the case of the exemplary configuration, $t_{wx_delta}=880\text{ns}$ thus follows from Figure 1. In case of large identifier differences, for examples $(ID - ID_{x-1}) = 250$ a wait time of over $220 \mu\text{s}$ thus results. This means that in the case of a required cycle time of, for example, $200 \mu\text{s}$, [telegrams] signals with high identifiers, cannot be transmitted at all. Furthermore, the net data throughput also [sinks] decreases with the use of small IDs with t_{wx_delta} becoming greater.

The objective of the invention is to provide an operational process for a data bus for a plurality of nodes in which the degree of efficiency is increased by [the] reducing the wait time between the [telegrams] signals to be transmitted [being reduced].

[The invention realizes this objective with the characteristics of claim 1.]

This solution consists [in brief] of adjusting the transit times delays, in particular between the nodes and the active star coupler. In the ideal case, this adjustment should be performed to the extent that the signal transit times between the nodes and the star coupler are equal. The measures according to the invention consist of adapting the fixed percentage of the wait time t_{wx0} individually.

The invention [will be concretized] is implemented by various measures which can[. These measures are the object of claims 2 and 3. They can] be applied jointly or alternatively. These measures are explained with the aid of the additional figures.

Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[Shown are:]

Figure 1 is an illustration of a star-shaped bus system having four nodes;

Figure 2 illustrates an example of data traffic on the data bus of Figure 1;

Figure 3 is an illustration of the calculation of the multiplication factor t_{wx} Δ ;

Figure 4 is a diagram [for the explanation of the measure specified in claim 2] showing the setting of the delay as a function of the last bus activity;

and

Figure 5 is a diagram [for the explanation of the measure] illustrating the synchronization of the nodes by adjusting each node wait time according to a transmit

time between the node and the star coupler [specified in claim 3].

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[As specified in claim 2 and represented] As shown in Figure 4, the nodes distinguish the transmitting and receiving case for the last bus activity. The node which has transmitted the last bus activity (sync pulse or [telegram] signal) waits [by] t_{min} longer than the [= all] other[] nodes which have received this bus activity. In place of the universal fixed percentage t_{wx0} a fixed percentage t_{wx0_tx} for the transmitting case or t_{wx0_rx} for the receiving case now appears.

$t_{wx0_tx} = t_{wx0_rx} + t_{min}$ is for transmitting case

t_{wx0_rx} is for the receiving case

The following wait time must be satisfied from the view of node A in order to avoid a collision.

Start time telegram ID = 2 > Receiving time telegram ID = 1

$$t_{wx0_rx} + t_{min} + 2*t_{wx_delta} > t_{max} + t_{wx0} + t_{wx_delta} + t_{max}$$

For this it follows:

$$t_{wx_delta} > 2*t_{max} - t_{min}$$

Thereby the value of t_{wx_delta} can be reduced from 880 ns to 700 ns in the exemplary configuration of Figure 1.

In addition or alternatively, [as specified in claim 3], the fixed percentage of the wait times t_{wx0_tx} and t_{wx0_rx} for each node can be [is] adapted to its individual delay time (here called delay_tln). This happens according to the following formulas.

- $t_{wx0_tx_tln} = (\text{idle_min} - t_{wx_delta})_{\text{tin_max}} + \text{delay_tin}$
- $t_{wx0_rx_tln} = (\text{idle_min} - t_{wx_delta})_{\text{tin_max}} + \text{delay_tin}$

The parameters used herein have the following meaning.

Table 1

Parameter:	Meaning:	Example:
delay_tin	Maximal delay of a signal from the electrical part of the star coupler to the node tln in the worst case	$\text{delay}_{\mu P}, \text{delay}_{\mu C1}, \text{delay}_{\mu 2}$
delay_tin_max	Maximum ($\text{delay}_{\text{tln_1}}, \text{delay}_{\text{tln_2}}, \dots$)	Here: $\text{delay_tln_max} = 240 \text{ ns}$
idle_min	Minimal "Bus Idle" time between telegrams	1100 ns
t_{wx_delta}	Multiplicative factor of the wait time	In the ideal case: t_{max}

If these equations are applied to the bus configuration of Figure 1, then the parameters follow as entered in Figure 5 for the individual nodes. In Figure 5 the signal curves are furthermore shown which the individual nodes see at their bus connection.

It can be seen from Figure 5 that, by the adaptation of the fixed percentage of the wait time t_{wx0_tx} and t_{wx0_rx} , the nodes are synchronized. The start time of a [telegram] SIGNAL then no longer depends on the different signal transit times in the system (from optical and in a given case electrical transmission segments from and to the star coupler) but rather only on the identifier of the [telegram] signal to be transmitted and the[, in a given case,] allocation of the data bus by a (more important) [telegram] with lower identifier. If the nodes would all transmit one and the same telegram with an identical identifier, they would do this simultaneously. Since only one node transmits each telegram with a certain identifier, a collision of [telegrams] signals is [ruled out] avoided.

Thus the following now applies.

$$t_{wx_delta} >= t_{max}$$

Thereby a halving of the multiplicative percentage of the wait time t_{wx_delta} is achieved. In the exemplary configuration of Figure 1 this means for t_{wx_delta} a value of 440 ns with respect to 880 ns. High identifiers, for example, ID = 250 have a wait time of ca. $t_{wx} = 110 \mu s$ and therefore can still be transmitted within a cycle of 200 μs .

Since in the normal bus operation many different and, thus, also higher identifiers are used, only rarely are directly sequential identifiers transmitted within one frame. Thus the halving of t_{wx_delta} causes approximately a halving of the

11

wait times t_{wx} . This has, in turn, the effect of nearly [a] doubling [of] the net rate of data throughput. [as a consequence]. Overall, therefore, the degree of efficiency of the protocol is increased. In the case of a fixed net data rate, the gross rate of data throughput can thus be lowered. Thereby cost reductions are possible due to the lower frequency of signals[, for example,]. [the] The EMC protection can be structured more simply [and not such high demands must be made of] with such stringent requirements for the structural parts.

For the realization of the invention, adaptation and logic elements not represented are provided in the nodes which perform the specified adjustments of the starting time points for the [telegram] signal as a function of the immediately preceding activity (transmitting or receiving) of the node itself and the individual signal transit time between the node and the star coupler. [Since as shown] Because significant transit time differences between nodes with electrical connection and the nodes with optical connection are present, it is sufficient to approximately compensate these transit time differences by delaying the transmission of only the node with electrical connection by a time span which is approximately equal to the average delay time of the node of the other type (with optical connection). A sufficiently [close] short time value follows, for example 210 ns.

The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting.
Since modifications of the disclosed embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.